# A PRELIMINARY REPORT

BY

J. B. LIPPINCOTT,

RESIDENT HYDROGRAPHER, UNITED STATES GEOLOGICAL SURVEY,

RELATING TO THE

# STREAM MEASUREMENTS

AND

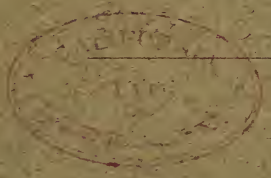
# RESERVOIR SURVEYS

MADE IN CO-OPERATION WITH THE

CALIFORNIA

WATER AND FOREST ASSOCIATION

DURING THE FIELD SEASON OF 1900



(TO BE FOLLOWED BY A DETAILED PUBLICATION, WITH MAPS, DIAGRAMS AND VIEWS.)

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## LEGISLATION.

The organic law, from which has grown the present work of the Geological Survey, is dated March 3, 1879. It creates the office of the Director of the Geolgoical Survey, and states that "this officer shall have the direction of the Geological Survey and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain." A fundamental function of the Survey is, therefore, the classification of the public lands, a work which can not be accomplished until a thorough knowledge is had of the water resources, since, for the most part, the public lands are within the arid region. The Geological Survey has not only to do with fundamental scientific problems relating to the earth, but more largely with present and prospective developments of mineral resources and products. Throughout much of the United States the principal mineral of economic value is water, and the study of the distribution and fluctuation of the water supply is among the most important of the functions of the Survey.

The work of the Survey is not confined to the public lands, for later Acts of Congress have extended its operations to the "national domain," which includes all of the territory within the possession of the United States. In every State and Territory surveys have been, or are being made. The extent of these is governed by many considerations, such

as the economic and scientific importance of results, *and the aid or co-operation of individual States.*

From the initiation of this Survey, in 1879, much attention has been given to the arid region, its great possibilities having been early appreciated. In 1877 the Director was called upon by Congress to consider the question of Federal recognition of the irrigation subject, and in March, 1888, a resolution was passed requiring the Secretary of the Interior, by means of the Director of the Geological Survey, "to make an examination of that portion of the arid region of the United States where agriculture is carried on by means of irrigation, as to the natural advantages for the storage of water for irrigating purposes, with the practicability of constructing reservoirs, together with the capacity of the streams and the cost of construction and capacity of reservoirs, and such other facts as bear on the question of storage of water for irrigating purposes."

In October, 1888, an appropriation was made for the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation, and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation and the prevention of floods and overflows.

In an Act approved August 30, 1890, it is specified that reservoir sites heretofore located or selected shall remain segregated and reserved from entry or settlement, and reservoir sites hereafter located or selected on public lands shall in like manner be reserved from the date of the location or selection thereof. In a subsequent Act, approved March 3, 1891, it is provided that the reservoirs shall be restricted to the lands actually necessary for the construction and maintenance of reservoirs.

By the Act of August 18, 1894, a specific appropriation was made "for gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in arid and semi-arid sections." In later acts there has been included the preparation of reports upon the best methods of utilizing the water resources of these sections.

## MAPS AND ESTIMATES.

Under the authority thus given work has been carried on systematically by the Division of Hydrography, and each year reservoir sites have been discovered and surveyed. In the discovery of reservoir

sites assistance is given by the Division of Topography in the preparation of contoured maps showing elevations of the surface. These maps also furnish information concerning the extent and character of the catchment areas tributary to various streams.

Differences exist in the character of the surveys in various localities. In many places only a reconnaissance has been made, this being sufficient to develop the fact that a suitable basin exists. At the other extreme, detailed surveys of some localities have been made, showing by contours at 1-foot or 5-foot intervals the entire basin to be flooded, and also on a larger scale the site of the proposed dam. Borings to bed-rock have also been carried on, the Survey being in possession of two complete diamond-drill machines with all the equipment for work of this character. From the maps and borings estimates of the cost of construction have been prepared, and plans drawn showing the character of structure proposed, the information being complete for making an appropriation for construction. As a matter of course, if an appropriation should be made, the constructing engineers would modify many features, but the examinations have been carried far enough to afford a close approximation of the cost. A considerable number of reconnaissance surveys can be made during the field season, but large expenditures are required for detailed examinations, so that it has been possible to complete comparatively few of the latter.

The reservoir sites surveyed or segregated have been listed or described in various annual reports of the Survey, beginning with the Eleventh. Reference should be made to these volumes for details. During the year 1899, surveys in great detail were made of three sites on the Gila River in Arizona, and of one large reservoir in Hetch Hetchy Valley on the head waters of Tuolumne River, California, also of several sites on the Rio Grande in New Mexico. The results of these surveys will be given in the Twenty-first Annual Report.

It is proposed to continue these surveys as *rapidly as funds may be available,* giving precedence to those where results have the *greatest public importance and interest.* As a result of several years' experience, the Geological Survey has a corps of competent engineers, together with instruments and equipment, and is carrying forward the work more rapidly and economically than such work ordinarily can be done by private or corporate enterprise. The question of expense has been carefully considered, and the methods in use have been adapted to secure the maximum efficiency at a minimum cost, consideration being given, of course, to the importance and the permanent character of the results.

## EXTENSION OF SURVEYS.

The Geological Survey is often requested to examine reservoirs in this and that locality, and is asked to do work the aggregate cost of which would far exceed its available funds. With the amount of money that has been appropriated it is possible to do only a limited amount of work each year, and it has been found economical to follow somewhat closely the progress of the topographic mapping. *If the public in general take an interest in the matter, and funds are provided, work can be expanded by an increase in the corps of skilled men.*

Another question frequently asked is whether the Government will build these reservoirs. That is a subject on which this office cannot express an opinion. The duty of the Survey is to ascertain the existence of reservoir sites and the cost of storage works, whether these are ultimately built by individuals, by corporations, or by the State or Federal Government. Some of the reservoirs surveyed or examined have already been constructed, others may be, but the most important are of such magnitude that they can not be built except by the use of public credit in one form or another. It is to develop these facts that examinations are being made, so that intelligent action can be taken by the people.

## CO-OPERATION.

In pushing forward these reservoir surveys co-operation is sought wherever practicable, as in the case of topographic mapping. In several of the States there is an arrangement by which work within the State is pushed forward more rapidly than otherwise would be possible. This results from the State making an annual appropriation to help defray field expenses. An equal or greater amount is spent in field work by the Geological Survey, and the resulting data is prepared and published by the latter, proper credit being given to the State authorities.

## SUMMARY.

The relation of the Geological Survey to reservoir surveys may be summed up as follows:

The survey was created primarily for the purpose of examining and classifying the public domain, including the mineral resources and the waters.

It is specifically authorized to survey reservoir sites and to ascertain the extent to which the arid region can be redeemed by irrigation.

It is making general explorations for the reservoir sites and surveying a few of these in detail each year.

*It will extend its operations as fast as funds will permit, the work being more rapidly advanced where State co-operation can be had.*

Its officers have no concern with the question whether these reservoirs are to be built by private capital or by public funds, their work being to ascertain the facts, such as capacity and cost of reservoirs.

There has been surveyed and published by the Geological Survey, topographic maps covering an area, in California, of 51,630 square miles.

These topographic maps are made by field surveys, controlled by triangulation and spirit levels. Frequent monuments of stone or metal are placed throughout the surveyed district, giving absolute elevations and geographic position. The contour lines on the map show elevations of all points, and political divisions and culture, (i. e., roads, houses, etc.) are also clearly indicated.

The maps are published by the Government in sheets (often called quadrangles) which are approximately 16x20 inches square, and are printed in three colors. They are sold for five cents each, or for $2.00 a hundred, by the Department, which is the cost of printing and mailing. They are particularly important in considering all engineering problems and are the base maps for subsequent geological and hydrographic work. They are also the standard maps used by the Government in all its various departments.

## HYDROGRAPHY.

The hydrophaphic work of the Geological Survey was begun in the State of California, under the direction of William Hammond Hall, about 1888, and was continued for two or three years, and then abandoned. The results of these investigations are contained in the 12th Annual Report of the Geological Survey, Part 2, and the 13th Annual Report, Part 3.

The present organization of the hydrographic work in the West provides principally for the employment of resident engineers in civil life, who have become familiar, from a number of years' experience, with their respective districts. These men are frequently connected with the State Universities, or State Engineering Departments. In California the work is under the direction of J. B. Lippincott, Resident Hydrographer, of Los Angeles.

The work is of three classes, Stream Gagings, Reservoir and Power investigations, and the study of underground water. On the stream selected for study a local observer is employed, living near the gaging station, a gage rod is placed in the river, and the local observer notes the river heights thereon one or more times each day. At intervals of a few weeks the station is visited by the Resident Hydrographer, or one of his assistants, and meter measurements made of the stream discharge. The height of water on the gage rod is noted at the time that the discharge measurement is made, and such frequent measurements at varying river heights, establish the ratio between river height and discharge. From these ratio, discharge tables are prepared, giving probable volumes for the intermediate river heights, and this permits of the preparation of tables of daily discharge of the stream from daily rod readings. In this way observations are being carried on in California at present, on the Sacramento River at Red Bluff; the Stanislaus River, at Oakdale; the Salinas River, near Salinas; the Tuolumne River, at La Grange; the San Joaquin River, at Herndon; the Kings River, at Red Mountain; Little Rock Creek, near Palmdale; the Santa Ana River, near Redlands, and records are also being furnished, without charge to the Survey, on the Kern River, near Bakersfield, by the Kern County Land Company; the San Gabriel River, near Azusa, by Mr. H. F. Parkinson; the Mojave, at Victor, and the Sweetwater River, near San Diego. Very great assistance has been rendered in this work by the courtesy of Mr. William Hood, Chief Engineer of the Southern Pacific Railroad, who instructs his bridge watchmen to furnish reports of river heights upon streams crossed by their road at which they have bridge watchmen. This corporation is also rendering very great assistance to physical investigations in California by keeping temperature and rainfall records at all their railroad stations, and by temperature records of streams for the Fish Commission.

It is scarcely necessary, in California, to speak of the value of these hydrographic records. Water is the life blood of the land, and a knowledge of it is of prime importance. The records of these river investigations are immediately published at the end of each year in what are known as Irrigation and Water Supply Papers, which are distributed upon application, by Mr. F. H. Newell, Hydrographer, Washington, D. C. The purpose of these Water Supply Papers is to immediately place the year's observations at the disposal of interested parties. There is also prepared, with more elaboration, a digested report of the results of the year's work, in the Annual Reports of the Division of Hydrography. These reports usually appear from six to

ten months subsequent to the expiration of the calendar year, and contain tabulated summaries of the year's work. They are also distributed upon application of interested parties.

In the investigations of the public domain, and the resources thereof, the Hydrographic Division of the Geological Survey is making surveys of reservoir sites in important districts. The funds available for this work are limited, and the work necessarily progresses with relative slowness in so great an area as the arid region of the United States. These surveys are made, in many cases, with considerable detail, and estimates prepared upon the size of the reservoir site; cost of impounding water therein, the probable water supply, and the value of the stored water. The results of this work are published in the Annual Reports. They are of value in calling the attention of individuals, corporations and States, to the possibility of developing local water supplies. Where co-operation in this work is offered it is the policy of the Survey to increase the work in these localities, and to expend larger sums where the larger results are thereby obtained. The following is a table showing States which have co-operated in these investigations with the Geological Survey, and the amounts which they have so far appropriated in this work:

| | Appropriated by state. | Total cost to date. |
|---|---|---|
| Massachusetts | $40,000.00 | $107,845.00 |
| Connecticut | 25,000.00 | 48,555.00 |
| Rhode Isalnd | 5,000.00 | 11,212.00 |
| New Jersey | 40,000.00 | 85,965.00 |
| New York | 86,000.00 | 216,000.00 |
| Pennsylvania | 40,000.00 | 17,000.00 |
| Maryland | 7,000.00 | 35,000.00 |
| Maine | 5,000.00 | 3,500.00 |

To summarize, the reasons for co-operation in hydrographic work, and the value thereof, may be stated as follows:

1. An extended record of discharge of a stream shows the area normally irrigable; with safety, from that stream, as well as the power possibilities; and indicates, together with reservoir surveys, the volumes of winter and flood water available by storage.

2. The stream records are an official basis for the legal adjudication of water rights.

3. They are essential in considering questions of domestic water supply, navigation and overflow.

4. The length of time required to establish average conditions, prohibits private investigation, and public construction of reservoirs is improbable without this information.

5. All this data is officially distributed, either free, or at the bare cost of printing.

6. The topographic maps are important for educational, engineering, poltical, administrative, statistical and economic uses.

7. The Geological Survey is now under the Civil Service; equipped and established by twenty years of service, and with experienced men, and outfits.

8. The State gets full value, at one-half cost.

In view of the above facts it is hoped that all friends of the development of California will aid in obtaining the co-operation between the State and the Federal Government.

## CO-OPERATION WITH THE CALIFORNIA WATER AND FOREST ASSOCIATION.

The California Water and Forest Association, appreciating the necessity of hydrographic investigation, has, by private subscription, brought about this co-operation with the Geological Survey. It is probably the first time in the history of the Geological Survey that a movement of this nature has been successfully executed by individuals, backed only by private subscriptions. This assistance is, therefore, very highly appreciated by the Geological Survey. In the future this burden should be taken by the State.

As a result of a conference held by Mr. Wm. Thomas, the President of this Association, aided by his corps of Consulting Engineers, the following agreement was entered into between the California Water and Forest Association and the U. S. Geological Survey:

### *MEMORANDUM OF AGREEMENT BETWEEN THE CALIFORNIA WATER AND FOREST ASSOCIATION AND THE UNITED STATES GEOLOGICAL SURVEY.*

### INVESTIGATION OF KINGS AND SAN JOAQUIN DRAINAGE BASINS.

The United States Geological Survey agrees to expend during the year 1900 the sum of Two Thousand Five Hundred ($2500) Dollars in making a reconnaissance of the drainage basins of the Kings and San Joaquin Rivers, and following this reconnaissance with a more detailed survey of reservoir sites discovered. It is the understanding that the Association of the Canals deriving their supply from the Kings River is to advance for the aid of this work the sum of Fifteen Hundred ($1500) Dollars, and that the California Water and Forest Association is also to advance the sum of One Thousand ($1000) Dollars, which sums are to be available for the work in question during the summer season of the year 1900 upon demand of the United States Geological Survey.

The Geological Survey does not agree at present to expend more than the sum of Two Thousand Five Hundred ($2500) Dollars in this work, and it is possible that reservoir sites in such number may be discovered that a larger amount will be necessary to complete sur- contributed to the Geological Survey, for engineering investigations, $3000.00, and has provided local subscriptions amounting to $3100.00,



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veys, than the aggregate of Five Thousand ($5000) Dollars mentioned above.

The United States Geological Survey is to have charge of the field work, select the men to be employed on the same, and is to pay their salaries. The Kings River Canals Association, and the California Water and Forest Association are to provide funds, on presentation of proper vouchers, for traveling, field and incidental expenses. The expenses of office work in preparing reports and plans for work is to be borne mutually in such manner that the ultimate cost of the entire work shall be equally divided between the Geological Survey, on the one part, and the Kings River Canals Association and the California Water and Forest Association, on the other part. In addition to the above, the Geological Survey agrees to maintain at its expense alone, the gaging station on the Kings River, at Red Mountain, and on the San Joaquin River at Herndon.

It is the understanding that in case of the unforeseen event of a failure to secure an apropriation to the Hydrographic Branch of the Geological Survey for the fiscal year 1900-01, that this Branch of the Department is relieved of its obligations in this contract, the other party to this agreement being likewise relieved.

The original maps and notes are to be kept in the archives of the Geological Survey, but copies of the maps and tracings are to be furnished on demand to the other parties to this agreement.

The Water and Forest Association is always to have an opportunity for having its Commission of Engineers inspect the work of the Geological Survey on this investigation, and upon the completion of this work, all plans and reports are to be submitted jointly to this Commission and to the Geological Survey. The commission is to be consulted with in connection with the character of the work in general, and is to advise with the Geological Survey.

In case this agreement at any time is unsatisfactory to the California Water and Forest Association, upon due notice it may be terminated.

## BASIN OF THE SALINAS RIVER.

The United States Geological Survey agrees to employ Professor C. D. Marx, of Stanford University, for the investigation of the reservoir sites in the drainage basin of the Salinas River. Professor Marx is to be supplied with such instruments and apparatus as may be necessary for the prosecution of his work by the Geological Survey.

For the purposes of this work the Geological Survey agrees to provide the sum of Five Hundred ($500) Dollars, expendable during the year 1900, preferably prior to July 1st. In addition to this, the Geological Survey desires to maintain the gaging stations on the Salinas River at its own expense, and to have the reports of such gagings reported to that department. The California Water and Forest Association on its part agrees to provide Professor Marx with Five Hundred ($500) Dollars to aid in the investigation of the storage possibilities in this drainage basin. The accounts are to be adjusted so that the ultimate cost will be born equally by the parties to this agreement. Professor Marx will be expected to make a written report to the United States Geological Survey of all the work which he may perform in the investigation of the storage possibilities on this stream, and also duplicate copies of this report to the California Water and Forest Association. In case it is found necessary to make detailed surveys of reservoir sites which may be found in the basin of this stream, the California Water and Forest Association agrees to provide the further sum of One Thousand ($1000) Dollars for the survey of these reservoir sites. (Since this agreement was made this further sum has been appropriated by Monterey County, and the Geological Survey has allotted a similar additional One Thousand ($1000) Dollars.

## YUBA RIVER.

The United States Geological Survey agrees to provide the sum of Four Hundred and Fifty ($450) Dollars to gauge the Yuba River and its tributaries during the summer season of the year 1900. This work is to be placed in charge of Marsden Manson, C. E., who is to employ such assistants as he may elect, and is to make report to the United States Geological Survey of all gaugings which he may have made, and write a report on said work for both parties to this agreement. The California Water and Forest Association on its part, agrees to expend a like sum of Four Hundred and Fifty ($450) Dollars in the prosecution of this work by Mr. Manson.

## CACHE CREEK.

The United States Geological Survey agrees to expend during the year 1900 the sum of Two Hundred and Fifty ($250) Dollars in making a reconnaissance of the drainage basin of one (1) stream (Cache Creek), on the Western side of the Sacramento Valley. The California

Water and Forest Association to provide a like amount for this purpose. This work is to be placed in charge of the United States Geological Survey to conduct as it may elect. The adjustment of accounts on this work is to be so made as to cause the expense to fall equally upon both parties to this agreement.

## MIDSUMMER GAUGINGS OF STREAMS.

The California Water and Forest Association agrees to provide the sum of Three Hundred ($300) Dollars for making one gauging each of as many of the streams as feasible, of the Central Valley of California, during the period of their low summer flow, and the United States Geological Survey agrees to expend a similar amount in this work. Such work to be under the charge of the Geological Survey, and reports to be made both to the Geological Survey and to the California Water and Forest Association. The adjustment of accounts in this case to be such as to equally distribute between the parties hereto the total cost of this work.

The Board of Engineers of the California Water and Forest Association is at all times to have access to the notes of the surveys mentioned above, and to have the privilege of inspecting all work and of advising as to its general character. And in case they may decide that it is desirable to discontinue this agreement on the part of the California Water and Forest Association, upon due notice it may be discontinued.

## LOCAL ASSISTANCE.

In addition to the above, an Association has been formed of the Canals diverting water from Kings River to aid in this work, and this Association, representing over 300,000 acres of irrigable land, contributed to the funds of the Water and Forest Association $1500.00 for investigations on Kings River .On Cache Creek the local commercial organizations at Woodland, have contributed $250.00 to assist in investigations on that stream, which investigations have been conducted by A. E. Chandler, of the Engineering Department of the University of California. On Stony Creek, similar organizations in the neighborhood of Willows, have contributed $250.00 for investigations there, and the Association and the Geological Survey have each contributed $500.00 to aid this work. In the Salinas Valley, the County of Monterey has appropriated $1000.00 to aid in the work in that locality.

To summarize, the California Water and Forest Association has

making $6100.00, and the Geological Survey has agreed to expend, and has largely disbursed, irrespective of administrative and office expenses, $7825.00 for this work; in all, $13,925.00 worth of work is the result of the effort on the part of the Water and Forest Association, and of its expenditure of $3000.00 in co-operation with the Geological Survey.

In addition to this, this Association has been of great service to the Hydrographic Division of the Geological Survey in assisting, through the California Congressonal delegations, and otherwise, in obtaining an increased Federal appropriation, from $50,000 to $100,000, for hydrographic investigations for the present fiscal year.

## PROGRESS OF ENGINEERING WORK.

The purpose of this progress report is merely to summarize, in a brief way, the results of the work performed during the past season. Detailed and revised reports covering these investigations will be published, fully illustrated with maps and photographs, by the U. S. Geological Survey.

## KINGS RIVER.

In order to proportion the contributions of the various canal companies deriving their water supply from Kings River, each company stated the area covered by its canal, and the following is a copy of these reports:

| | | |
|---|---|---|
| Fresno Canal, whole system | 160,000 | acres |
| Laguna Canal | 25,000 | " |
| Alta Irrigation Company | 50,000 | " |
| People's Canal | 25,000 | " |
| Last Chance Canal | 25,000 | " |
| Centerville | 20,000 | " |
| Murphy Slough Association | 20,000 | " |
| Lower Kings River | 15,000 | " |
| Fowler Switch Canal | 12,000 | " |
| Stinson Canal | 12,000 | " |
| Crescent Canal | 12,000 | " |
| Emigrants' Canal | 3,000 | " |
| Liberty Canal | 750 | " |
| | 379,750 | acres |

These figures probably are the total area irrigable under each canal rather than the areas actually irrigated.

The capacity of all the canals leading out of Kings River is stated to be approximately 4000 cubic feet per second, and the low water summer supply of this stream falls as low as 150 cubic feet per second. It is, therefore, evident that this late summer supply is wholly inadequate for the demands of the water companies. The division of this late water has resulted in much litigation, and it is estimated that these canal companies have expended annually, aproximately $40,000.00 in legal controversies over it. This represents 4 per cent interest on $1,000,000.00, besides resulting in much bad feeling, and no actual development. It is apparent that many varieties of crops, particularly the citrus fruits, and alfalfa, cannot be grown on such an intermittent water supply. During the spring months and early summer there is an excessive water supply for all companies, and there is much water unused. Similar conditions prevail during the winter months. If summer water could be supplied with certainty it is believed that midwinter irrigation would be practically abandoned. If it were possible to supply a reasonable amount of water during the late summer months, many varieties of crops could be grown which are impossible under existing conditions, and it would be entirely feasible to greatly extend the irrigated areas, especially along the foothills where citrus and other high-priced fruits can be grown. During the past season, under present conditions, the profits from the irrigated districts around Fresno have exceeded, it is estimated $2,000,000.00. This is a fair sample of what could be done by extending the irrigation idea throughout the Central Valley of California.

These various canal companies of Kings River, have organized for the purpose of co-operating for the increase of the late summer supply of water, and have decided that it is more profitable to expend money on construction than in litigation. These are the motives of the Kings River storage Association in backing the movement of the California Water and Forest Association and the Geological Survey. They considered that they would be able to build a storage reservoir or a water developing plant in case a reasonable proposition should be presented to them, at an annual interest expense not to exceed that now spent on litigation.

The requisites of a reservoir site are numerous and exacting.

1. There must be an available water supply sufficient to fill the basin.

2. There must be a a basin to hold this supply.

3. There must be a good dam site.

4. There must be good materials to make a dam of.
5. The foundations must be satisfactory to sustain the dam.
6. There must be available lands to put the water upon.
7. The entire project must be on a commercial basis.

There were, on Kings River, a large number of sites which were popularly supposed to be good, but which proved defective, owing to the lack of some one of these vital requisites.

## ORGANIZATION.

In the investigation of the large district of Kings River, which section was, from a scientific standpoint, practically unknown, it was decided to equip two parties for the season's work. A reconnaissance party was organized, in charge of Mr. E. G. Hamilton, Topographer, of the Geological Survey. The work of this party consisted practically of exploration. Mr. Hamilton was instructed to visit all portion of the drainage basin; to make instrumental examinations of all possible reservoir sites, and at the end of each month to report to headquarters the character of such sites found. Where sites of merit were observed upon by the reconnaissance party, they were noted. A second party was organized, under the direction of Mr. H. E. Green, an engineer of extended experience in construction of storage reservoirs, for the purpose of making more detailed examinations of the better sites found by the exploration party. These were surveyed in detail. The reconnaissance party visited and reported upon seven reservoir sites, and the survying party surveyed four reservoir sites.

The following instructions were given to the Engineers for reports on the reservoir sites:

## REPORT ON RESERVOIR SURVEY.

1. Give name of Engineer in charge, and date of survey.
2 Name of locality.
3. Streams tributary to site.
4. Land title to site.
5. If possible tie reservoir surveys to land surveys. The point of reservoir survey to be tied in, is preferably the ends of the dam.
6. If the land is not subdivided, tie reservoir survey to prominent natural objects.
7. Estimate area of tributary drainage basin.

8. Give general statement of elevation of drainage basin and elevation of reservoir site.

9. State whether drainage basin is timbered, or bare hills.

10. Compute water supply.

11. Give capacity of reservoir with various heights of dam.

12. State character of material for dam; earth, rock fill, or concrete.

13. For purposes of preliminary estimate, consider:—

Earthen dam—20 feet wide on top; 2½ to 1 slope on inner face, 1½ to 1 on outer face. Describe the quality of the available earth, which should be clay and sand, also give length of haul.

Rock Fill—20 feet wide on top; 1½ to 1 outed slope; one to 1 inner slope. State position of available rock supply; give probable cost of cement, delivered on the ground, and available timber for inner face, and cost thereof.

Concrete Dam—State the proximity and relative elevation of quarries; the cost per barrel of cement, delivered on the ground.

14. Report on probable foundation for dam.

15. Estimate on cost of dam.

16. Estimate *cost* per acre-foot of water stored, and *value* per acre-foot of water stored.

## RESULTS OF SURVEYS ON KINGS RIVER.

In this preliminary report only the more favorable sites investigated are referred to. In the final printed reports this will be given in detail.

## SUMMARY OF H. E. GREEN'S RESERVOIR SURVEYS.

Mr. H. E. Green surveyed in detail the Long Meadow reservoir site. This site is 5200 feet above sea level, on Ten Mile Creek, four miles above its junction with Kings River, and is located in T. 13 S., R. 28 E., M. D. M. There is approximately 25 square miles of drainage basin. Both reservoir site, and most of this drainage basin, are owned by the Sanger Lumber Company. The mean rainfall is estimated at about 45.3 inches, and the mean run-off at 25,000 acre feet, which is less than 50 per cent of the rainfall. On the basis of 2 feet per square mile, which is not an unusual condition in drainage basins of this type, the run-off tributary to the dam site would be 36,500 acre feet. A dam at this location 170 feet high, would give a reservoir contents of 25,330

acre feet. The most economical type of dam is a rock fill, or loose rock dam, with a plank face. The total cost of this structure is estimated at $709,757.00, or at the rate of $28.00 per acre foot of storage capacity. This is the cheapest type of dam that could be built here, and the high rate per acre foot manifestly condemns the proposition.

Several small lakes near the summit of the range were investigated during the season. East Lake was surveyed, and found to have a capacity, within reasonable limits, of 4554 acre feet, and Reflection Lake, near by, of 700 acre feet. These lakes apparently are formed by slides of loose rock, or glacial morains, which have clogged up the natural drainage lines. Water readily passes through this loose rock, and it is believed that it would not be practical to obtain impervious foundations to bed rock on this class of material. The cost of delivering cement at these sites would be from $15 to $20 per barrel, owing to their inaccessibility, and as reservoir propositions they are condemned as impractical.

Granite basin reservoir site, situated between the South and Middle Forks of Kings River, and between Kanawyer's store and Simpson Meadows, was visited, and preliminary survey made thereon. The elevation of the reservoir site is approximately 10,000 feet. There are two outlets from the basin requiring dams, one, 750 feet long on top, and 140 feet high, the other, 900 feet long, and 130 feet high. The capacity of this site would be 10,350 acre feet. The drainage basin does not exceed 6 square miles and the location is exceedingly difficult of access. It is therefore believed that this site is not one of merit.

The first portion of the summer season of 1900 was spent in exploring for reservoir sites in the higher portion of the Kings River drainage basin, and these investigations proved generally unsatisfactory. Because of these conditions, about September 1st, the party in charge of Mr. H. E. Green was instructed to begin an investigation of the possibilities of obtaining a water power on Kings River; this power to be used for developing electricity, which would be utilized for pumping around Fresno. At the same time Mr. Louis Mesmer, of the Geological Survey, was instructed to begin a study of the underground water in the district irrigated from Kings River. Mr. Lewis A. Hicks, who has developed such a remarkable pumping plant for the Kern County Land Company, near Bakersfield, was employed, because of his successful experience in that locality, to make estimates on the cost of performing this pumping, on the assumption that power sufficient to raise 500 cubic feet per second water, or 1000 acre feet per day, could be obtained from Kings River. These reports follow in their proper order.

## PRELIMINARY ESTIMATE OF COST OF CONDUIT TO GENERATE 6500 HORSE POWER.—H. E. GREEN.

This estimate embraces the necessary works from the intake to the penstock.

*DESCRIPTION—*

The works will be situated in one of the canyons of Kings River.

The tunnels will be granite and ulined; 6x6 feet, in the clear.

Adits when in canyons will be arched over, allowing storm water a clear way.

*COST OF WORKS—*

| | |
|---|---|
| Road into Canyon, 6 miles, at $8500.00 | $ 51,000.00 |
| Bridge across South Fork | 2,500.00 |
| Trails, 6 miles, at $500.00 | 3,000.00 |
| Tunnels (Burleigh Work), 14,000 feet at $12.00 | 168,000.00 |
| Headworks | 5,000.00 |
| Adits to tunnels, 14 at $500.00 | 7,000.00 |
| | $236,500.00 |
| Engineering and contingencies, 15 per cent | 35,475.00 |
| | $271,975.00 |

Observations covering a period of 15 months, being July, August and September, of the years 1896 to 1900, inclusive, demonstrate the fact that had the proposed tunnel conduit been in operation during the above mentioned time, it could have been filled to its maximum capacity of 180 second feet, during the whole of July of each year. During the whole of August of the same years, the tunnel could have been supplied with 100 sec. ft. of water, and for 75 per cent of the time could have had 150 sec. ft.

During September of the above five years, three-fifths of the time a supply could have been obtained of 100 sec. ft., and an average of 85 sec. ft. during the exceptionally dry years of 1898 and 1899.

With the proposed 650 feet head, the 85 sec. feet would yield 6250 h. p.

During all the remaining months of the year, the conduits would have been full, supplying 13,300 h p.

*WELL OBSERVATIONS—*

The district irrigated from the Kings River Canals was inspected, to determine the underground water supply, between September 24th and November 13th, 1900. During this time over 850 wells were visited, and the various features of interest concerning them determined where possible. This included an examination of the quality of the water, the strata through which the well had passed, the depth to the water plane, the general character of the well, the amount of supply available, the location of the well, the owner's name, etc. A map has been prepared, showing the location of each well and the depth of water plane at that point, for an area extending practically from the San Joaquin River to 8 miles South of Hanford. This map will be presented with the final report. In a general way it shows that Northerly and Westerly from Fresno the water plane is at a depth of approximately 15 feet from the surface; that between Fresno and Kings River the depth is approximately 10 feet, and between Kings River and Hanford the depth is about 15 feet. In the district lying under the Alta Irrigation Districts Canal and the water plane varies from 15 to 30 feet.

The soil throughout the locality is, to a large extent, granetic sand, and below an average of ten or fifteen feet, is thoroughly charged, or saturated, with water.

*QUALITY OF GROUND WATER—*

The surface water is more or less alkaline, and it is not advisable to use it for irrigation. Water below a depth not to exceed fifty feet, can be considered satisfactory for irrigation. This is based on the test made of all wells in the district, some of them being taken from the sections where there were the strongest alkaline surface indications. In every case the water was found to be good. When the surface strata are penetrated this water rises to the elevation indicated in the preceding paragraph.

There have been but few attempts to pump water in any larger quantities than required for domestic purposes, but this supply is universally ample from a two inch screw pipe put down to an average depth of fifty feet, landing the pipe on a strata of clay, and then boring through the clay and allowing the water to come in from the bottom of the hole. It is the common impression that by boring through two or three strata of clay or hard pan, all the surface water is shut off, thus exempting the consumers from one of the supposed causes of malaria. The impression is not intended that one could not obtain an

abundant quantity of water at twenty or thirty feet, but the quality would not be so good.

One of the largest pumping plans is that of the Fresno Domestic Water Company, the water supply for which is obtained from unperforated wells, at a depth of six hundred feet. In this case there is an ample supply for a city of 12,000 people from a lot 50x150 feet. Complete data on these wells is not yet obtainable.

A number of wells have been put down in, and around, Fresno, for street sprinkling. These wells are 8 inches in diameter, and not to exceed seventy feet deep, and are perforated, excepting, perhaps, the lower joint or two of the pipe, and the water practically all comes from the bottom. Good wells have been thus obtained, and with a 2½ H. P. engine, they fill a 1250 gallon tank, 9 feet above the surface, in five minutes, or at the rate of 250 gallons per minute, lowering the water plane during the pumping not to exceed five or six feet below normal elevation.

A few small pumping plants have been installed, one, five miles east of Fresno, on Minnewawa Ranch; several around Selma; two near Wild Flower; and in all cases yielding at least one-half second foot to a 7 inch unperforated well, not over twenty feet deep, with a lift not to exceed twenty feet in any case.

It is recommended that wells of about 10 inch or 12 inch casing be put down to a depth of about one hundred feet, in the average, and not perforated under fifty feet, thereby shutting off all possible chance of drawing from the more or less alkaline surface water. It is probable that they would furnish one and one-half second feet to the well.

A well driller in Selma, states that he would put down wells 12 inches in diameter, one hundred and fifty feet deep, guaranteed to furnish 1½ second feet to the well, without perforations, at a cost not to exceed $300.00 per well.

The permanent lowering of the water plane to a depth of about twenty feet from the surface, in the irrigation district between Fresno and Guernsey Station, South of Hanford, would largely check the accumulation of alkaline salts that are gathering every year and injuring seriously thousands of acres of good farming land. The application of the water for irrigation purposes then, would tend to carry off the salts, and the consequent redemption of most of this land.

To summarize, it may be stated that a water supply, ample in quantity, good in quality, and at average depths not to exceed 15 feet from the surface, can be obtained generally throughout this district, and it is believed that this supply would be satisfactory for irrigation purposes.

## PRELIMINARY REPORT ON PUMPING PLANTS—BY LEWIS A. HICKS.

While these estimates may be changed in detail by a more thorough study of the problem than has been given thus far, the conclusions may be accepted as a conservative estimate of the maximum costs for construction and operation.

### *WATER POWER—*

The physical data as to area, elevation and character of water shed tributary, the amount of run-off during the dry years just past, and the available fall which can be secured by a short development of conduits and tunnels, indicate that sufficient power can be continuously generated at the proposed power house site to provide the energy required for pumping and cover all losses incidental to its transmission and transformation.

### *TRANSMISSION—*

Two pole lines have been laid to Centreville, with distribution lines to Fresno and Hanford through the center of the irrigated districts.

The distances, climate factors and voltage selected are all well within the attained limits of existing lines and experience elsewhere, as it has been considered desirable to select a medium line pressure which will permit the use of standard apparatus already developed.

### *PUMPING STATIONS—*

The grouping of pumps has been planned to attain the greatest economy in cost of transmission lines, step-down trans-formers and motors, and also permit the most economical use of the water secured by the combined flow from several pumps to obtain a satisfactory irrigating head. The transmission voltage will extend to stepdown transformers of suitable capacity for four pumping stations situated a quarter of a mile or more apart radially from the transformer house.

Vertical 2,000 volt induction motors, direct coupled, will drive the centrifugal pumps, both motors and pumps being mounted in steel

frames, capable of adjustment in vertical and horizontal planes. Each station will be provided with mechanical devices for priming the pumps and an automatic switch throw for cutting out the motors from the line in case of disturbances.

The pits have been designed with a curbing of concrete panels reinforced with expanded metal and set in Tee steel frames, to remove the element of deterioration and fire risk from this usually perishable part of the plant.

*WATER SUPPLY—*

The character of the deposits of gravel, sand and clay which have been carried from the Sierras by the lateral drainage entering the San Joaquin Valley from the East is very similar throughout its length, and its formation is but the repetition on a tremendous scale of the familiar fan-shaped cone which may be seen wherever a small arroyo debouches from the hills into a wider valley of relatively flat gradients. The depth of these deposits in the San Joaquin Valley is known to be more than 1,000 feet, and in the process of filling up, the direction of the surface drainage channels shifted radially from the mouth of the canyon, and the heavier cobble stones and gravel soon deposited, while the finer sands and clays in suspension were carried on. As this process continued, and the water worn detritus built up the levels of the valley, the surface channels crossed and intersected the older channels beneath in every conceivable direction, so that while there is no continuity of strata laterally at the same depth, yet the whole country is so underlaid with channels that if water bearing sand is not found at any certain depth it is sure to be encountered somewhere in a vertical plane wherever wells are bored.

The delta of Kings River, comprising most of the irrigated territory covered by the Associated Canals, is characterized by a remarkably thick superficial strata of clay 15 to 60 feet in depth, which are underlaid with fine sand yielding a large amount of water through open bottom wells. This formation is more favorable to the development of large quantities of water than those further South where the clay strata are not of sufficient thickness to form a safe roof over the cavity produced in the sand by pumping, and perforation must be resorted to. The slope of the Kings River district at right angles to the axis of the San Joaquin Valley varies from 5 to 20 feet per mile and the gravel water storage thus afforded above the level of the valley supplies the underlying sand strata with water which has a well defined hydraulic grade and percolation toward the trough of the valley where

the heavy clay deposits cap the water-bearing sand and offer the requisite conditions for artesian pressures.

In dry years the most of the run-off of Kings River, amounting to 800,000 acre feet, is absorbed by seepage loss and irrigation of its delta lands, and it is probable that the mean annual infiltration from River, canals and irrigation exceeds one million acre feet.

The storage capacity of the area affected by this infiltration above the level to which the water plane might be reduced by pumping continuously can not be estimated at less than 2,000,000 acre feet.

The experience had in Kern County with pumping plans having a combined capacity of 75,000 acre feet annually, is that the water plane is maintained notwithstanding continuous pumping where the wells are in proximity to canals in use or where surface irrigation from gravity ditches takes place around the wells. The logical position for pumping plants is therefore in the center of the irrigated district near the canal lines, and the distribution should be so planned that the pumped water can be used in proximity to the plants, while the gravity canal water, thus released, which would otherwise have been required, is handled in larger volumes to the outlying districts beyond. This is only possible where there is an associated interest in the economical use of water through all the canals in rotation and well organized centralization of administrative authority for this purpose.

A careful study of the data furnished by the extensive survey of the water plane in the Kings River delta by Mr. Mesmer, together with my own inquiries from well-borers familiar with the district and my previous experience with conditions obtaining in connection with irrigation pumping on a large scale warrant me in stating that this water supply can be depended upon to furnish continuously a permanent supply of 300,000 acre feet per annum.

It will be necessary to sink test wells wherever permanent plants are contemplated and the expense of doing so has been considered in my estimates. Of 50 wells put down in Kern County, only 30 were considered suitable in all respects for the installation of pumps.

The question of land purchases for pumping stations has been considered on the basis that suitable location can be secured on lands owned by members of the Association, who would be willing to grant the Association ground room to the extent of one-quarter of an acre for the station, together with right of way for pole lines and ditches connected therewith for a nominal consideration.

*COST OF CONSTRUCTION—..*

The total cost of hydraulic development, electrical equipment, transmission lines and pumping stations, exclusive of local administration and interest charges during the construction might be stated as $3.50 per acre foot of developed capacity, on the basis of continued annual operation of the pumps. It should be remembered that while the pumps provide an acre foot of water very close to the point of use, the water from the most favorably located storage reservoir is subjected to a heavy loss from seepage in the channels through which it conveyed to the lands where used. These losses have been determined with precision for the Kern County Canals, which are similar to those under consideration on Kings River, and may be stated as 40 per cent of the total volume delivered into the head of the canals. This figure is applicable to present methods of distribution and may be materially decreased if proper rotative distribution were practiced. The conveyance loss on pump water will not exceed 10 per cent where properly used, and the virtual value of an acre foot of pump water is therefore ordinarily equivalent to one and a half acre feet of stored water.

*COST OF OPERATION—*

The actual cost of operation of such a plant as contemplated will amount to $157,530 per annum, made up as follows:

| | | |
|---|---|---|
| Interest, 6 per cent on bonded indebtedness | | $76,650.00 |
| Taxes, 2 per cent on 60 per cent valuation | | 15,330.00 |
| Depreciation and maintenance | | 25,550.00 |
| Operating Expenses— | | |
| Power House | $12,000.00 | |
| Pumping Station | 18,000.00 | 30,000.00 |
| Administration and local expenses | | 5,000.00 |
| Insurance and sundry expenses | | 5,000.00 |
| | | $157,530.00 |

This expense will remain substantially constant whether the pumps are operated or not, as less than 20 per cent of the total would be affected by discontinuing the operation of the plant.

The actual continuous operating time of all the pumps in a large system has been as high as 98 per cent of the total possible of attain-

ment, and the possible capacity of the present plant may be safely estimated at 90, or 1,000 acre feet by 365 days by .9 equals 328,50 acre feet, which, divided into the annual expense, gives 48c per acre foot as the expense of operation.

In this estimate the item of depreciation has been calculated from a consideration of the relative life of the various perishable elements entering into the plant, and the fund so provided will amply cover any possible deterioration and provide for the maintenance and renewal of the plant when necessary. The item of operating expenses represents conservatively the actual experience of existing pumping plants and pumping stations.

The daily capacity of the pumping plants has been designed for 1,000 acre feet daily to meet Mr. Nare's views as to the necessity of augmenting the mid and late summer supply to that extent, and if the beneficial use of the pump water is confined to that period, the cost per acre foot would increase to $1.05. The existence of a new supply of this magnitude would, however, insure the productive utilization of lands which are now without any assured rights to the benefits of prior appropriation, and I consider it reasonable to assume that sufficient revenue would be received from country lighting and the wholesale disposal of power in Fresno and Hanford during the periods when the river flow exceeds the diverting capacity of the canals to make the cost of pumping proportionate to the total capacity of the plant, or say, fifty cents per acre foot.

It seems proper, however, to consider the matter in its worst aspect, and for this purpose we may say that the cost of delivering stored reservoir water on the lands to be irrigated is the measure of unit prices which we can afford to pay for pumped water.

If the pumping plants were shut down from the 1st of March until the 1st of July, while the river flow is usually adequate, and received no revenue from any other source than pumping, the output and cost for the rest of the year would be: 8 months by 30 by 1,000 acre feet by .9 of time equals 216,000 acre feet, which, divided into annual expense, gives 75c per acre foot.

It may be said that this figure should be still further increased because no beneficial use could be made of the water during the fall months, but on the other hand, it is certain that the plant would never be shut down as there would always be some demand for surplus water, and experience elsewhere in the San Joaquin Valley demonstrates that forage crops are possible whenever water is available. These considerations lead to the conclusion that the cost of pump water on lands

under the Associated Canals by the methods indicated will not exceed seventy-five cents per acre foot.

Plans for the pumping station are being prepared, and the engineering data and estimates will be included in a final report.

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## PRELIMINARY REPORT BY E. G. HAMILTON.—DUSY MEADOW RESERVOIR SITE.

The Dusy Meadow reservoir site is situated in Fresno County, California, on the North Fork of the Kings River, in Section 36, Tp. 10 S., R. 27 W., and Section 31, Tp. 10 S., R. 28 W. The area of the water shed is 144 square miles. With a rainfall of 39 inches, and a run-off of 33 per cent, there would, on average years, be available for storage 88,000 acre feet. The elevation of the water shed is approximately 9000 feet. The elevation of the dam site is 6300. Rock and lumber are available for a dam of the rock-filled type. A dam 120 feet high, would store 16,850 acre feet, and would cost approximately $538,800.00, or $32.00 an acre foot. It is, therefore, not a reservoir site of value at present in view of other possibilities on this stream.

## SUMMARY OF REPORT ON CLARK'S VALLEY RESERVOIR SITE.

This reservoir site is situated in Fresno County, California, 16 miles East of the Southern Pacific Railroad station of Sanger. It lies between certain low foothills, and the main range, and commands in elevation all of the canals diverting water from Kings River except the Gould Ditch. It is situated within two or three miles of the headworks of most of the canals diverting water from Kings River, and the Alta Irrigation District Canal passes within a mile of the proposed outlet from the reservoir. It is not situated upon the main stream. The local drainage line is known as Watoke Crook, which drains 33 square miles of the Western face of the Sierras. The average elevation of this drainage basin is 1000 feet. Assuming the average rainfall in this local basin is 18 inches, and 33 per cent run-off, we would have 10,515 acre feet as the amount of water available for storage therefrom. As the local drainage basin is small, and as the reservoir site would be filled by a diversion canal from the main river, the silt problem would be eliminated therefrom. The elevation at base of dam is 429 feet, as determined by levels from the Southern Pacific Station at Sanger. The capacity of the reservoir, to the 80-foot flow line is 126,634, and to the 100-foot flow line it is 223,224 acre feet.

This basin is locally known as Clark's Valley. Three dams will be necessary to close all of the openings therefrom. The dams estimated upon are to be made of earth, which may be found in great abundance. The material is largely a reddish clay, containing gravel and sand. It is a soil such as is frequently found near the foothills of disintegrating granite mountains.

It is estimated that it will cost for the construction of dams to control the 100-foot water level, giving a storage capacity 223,224 acre feet, $1,311,842.00. This is on a basis of dams with a maximum height of 105 feet 20 feet wide on top, with slopes 2½ to 1 on the inner face and 1½ to 1 on the outer face, containing 6,559,210 cubic yards of earth. It is believed that this material can be placed, by mechanical devices, into position at a cost ranging from 17 to 20 cents a yard.

*CONDUITS—*

It will be necessary to construct approximately 10 miles of diversion conduits from Kings River to the head of the reservoir site. The entrance to the reservoir site will be by means of a tunnel through an in-

tervening granetic range. The line will consist of 7000 feet of tunnel, with 3600 feet of approaches, and 43,000 feet of canal, which will be partly in rock. A conduit to fill this storage reservoir should have a capacity of 1250 cubic feet per second, or sufficient to deliver 2500 acre feet of water per day. Spill ways, outlet tunnel, gates, and headworks, are properly estimated upon, and the total cost of construction, including right of way and sundry expenses, will bring the total cost of this project up to $2,013,949.00, or at the rate of $9.00 per acre feet stored.

Considering the entire cost of the work to bear 6 per cent interest, and taxes to be at the rate of 8-10 of 1 per cent of the cost and maintenance $10,000.00 per annum, we would have an annual charge against this work of $146,949.00. As this reservoir will be in the process of filling until approximately the first of July, and as the withdrawal for irrigation purposes will begin immediately thereafter, it would be fair to assume that the loss by evaporation will not exceed 2 per cent, so that there will be practically available for distribution to the canal system, about 220,000 acre feet.

With the annual charges at $146,949.00, and the total amount delivered from the reservoir 220,000 acre feet, the annul charge per acre foot will amount to 66.8 cents.

Most of the canals of Kings River, during the greater portion of the year's irrigation season are carrying some water, and it is reasonable to suppose that the greater portion of the loss due to seepage would be met, under any circumstances, by this initial volume. The increase loss due to the delivery of a larger volume of water through these canals is problematical, depending on the distance which the water will have to be conveyed. It might be a reasonable assumption that 25 per cent of this volume will be lost. The 66.8 cents per acre foot would then represent 75 per cent of the ultimate cost of the water delivered to the irrigators, or 89 cents per acre foot for water upon the field. It may be assumed that the cost of maintaining the distribution system will be the same whether water is run through them under present conditions, or regulated as described above.

85 *FOOT DAM—*

If the dams should be built to maximum height of 85 feet, impounding water to the 80-foot level, the diversion canal to fill this site should then be constructed to a capacity of 525 second feet. The lengths of the conduit would remain about the same, but the cross-section would be reduced. The grade of the conduit, however, would be so located as to admit of the raising of the dams to the higher level, in case it was found desirable in the future. Under these circumstances the cost of

completing the works would be $1,234,776.00. The resulting capacity would be 126,634 acre feet, or at the rate of $9.80 per acre foot of storage capacity. If we take in this case, interest on first cost, at 6 per cent, taxes at 8-10 of 1 per cent, and maintenance at $6,000.00, and consider that we lose 4634 acre feet by evaporation, we will have an annual charge, per acre feet stored, of 73.7 cents, and assuming that 25 per cent of this volume is lost in transmission to the irrigated lands, we will have an ultimate cost to the irrigator of 98.3 cents per acre foot delivered.

*WATER SUPPLY—*

It is assumed that 10,515 acre feet of water will be furnished from the local drainage basin tributary to this site. The storage capacity of the reservoir, with 105 foot dam, is 223,224 acre feet. This, less the 10,515 acre feet from local rainfall, gives 212,709 acre feet net, to be supplied from Kings River. In order to determine whether a canal with a capacity of 1250 second feet would fill this reservoir the following assumption have been made:

1st. That the total flow of Kings River, up to 1250 second feet, can be diverted to the reservoir during the months of November, December, January and February.

2nd. That the combined capacity of all canals diverting water from Kings River during the remaining months is 4000 second foot, and that any volumes in the river above this amount are available for storage.

The United States Geological Survey, during the past five years, has maintained a gaging station on Kings River near the proposed point of diversion of that stream. The past five years have been ones of unusual drouth, and it is believed that an estimate based thereon will be entirely conservative for the future. From these records of discharge, which are of essential value in this estimate, it is shown that during the season of 1897-98, which is the one of smallest flow, there could have been diverted by such canal 191,205 acre feet. If we add to this the supply from the local drainage, we have a total of 201,719 acre feet. This is 21,505 acre feet, or 10 per cent less than the maximum capacity of the reservoir, for the driest year, and this condition may possibly occur once in each generation. For the season 1898-99, which was also one of great drouth, there would have been available 213,219 acre feet, or 5 per cent less than the maximum storage capacity. For the remaining three years, the supply would have been ample. It is believed, however, that if a midsummer supply could be assured to the irrigators, that extensive irrigation will not begin to full

volume as early as March, or extend as late as November, and that some water will consequently be available during these months for storage. Under these conditions the supply would have been sufficient to have completely filled the reservoir.

*WATER SUPPLY FOR 85 FOOT DAM—*

By a similar argument it is shown that a canal with capacity of 525 cubic feet per second would have, on all years, filled the reservoir controlled by a dam with an 85 foot maximum height, without diverting any water during the months of October or March, except when it was more than the combined capacities of all the canals.

It might be stated that the diversion of water for this reservoir would in no way interfere with the use of the water of Kings River for power purposes.

## SUMMARY.

It is shown by the above estimates that it is feasible to construct a great storage reservoir at Clark's Valley, capable of supplying over 200,000 acre feet of water, and that the water is available to fill this resevoir. In case the supply was greater than was necesasry to furnish the lands now covered by canals under Kings River, it is believed that many thousand acres, which are not irrigated at present, could be brought under cultivation. These new lands would, in all probability, be best located along the foothills from Sanger towards Porterville, and it is believed that they would be of great value for the production of citrus fruits. These dry lands are now worth from $20.00 to $30.00 an acre. With a reliable water right it is believed that they would be worth from $100.00 to $150.00 an acre. If these lands could be furnished with this water supply to the extent of two feet in depth, at a cost of $18.00 to $20.00, gross, or an annual charge of $2.00 per acre, it will be seen that there is a large profit in the transaction. At present there is an ample supply of water to meet all demands on Kings River to the first of July. For approximately 100 days thereafter, during the growing season, there is a deficit during which the water from this reservoir could be drawn upon. If 223,000 acre feet of water is withdrawn in 100 days it would be equivalent to a continuous flow during that period of 1115 cubic feet per second, and it is probably a reasonable assumption to state that the productiveness of this greatest irrigation district in California, can be almost doubled by the erection of this work.

If the California Water and Forest Association succeeds in bringing about the construction of this one reservoir site, its efforts will have been amply rewarded.

## SALINAS RIVER INVESTIGATION.

The drainage basin of Salinas River was inspected in part, under the direction of Professor Charles D. Marx, of Stanford University. The examination consisted of a reconnaissance survey made during the months of May to August, inclusive, in the summer of 1900. The following Reservoir sites were examined:

### *FOSTER RESERVOIR SITE—*

The Foster Reservoir site is situated in Section 23, Township 19 South, Range 5 East, M. D. M., on the Arroyo Seco and Piney Creek. This reservoir site was surveyed in June, 1900. The lands are held largely in private ownership. There are 161 square miles tributary to the reservoir site. The dam estimated upon would be of concrete, 100 feet high, and 560 feet. A 100-foot dam would furnish 13,300 acre feet of storage capacity, at a cost of $248,000.00, or at the rate of $18.50 per acre foot stored.

### *THE CURRIER RESERVOIR SITE—*

The Currier Reservoir site is situated in Section 19, Township 19 South, Range 6 East, M. D. M. The dam would be 420 feet long on top. The survey was made in June, 1900. The reservoir site is situated on the Arroyo Seco, and the lands are held in private ownership. There are 184 square miles of water shed tributary to this site, ranging from 400 to 6000 feet above sea level. The dam would be made of concrete, and at 120 feet in height would have a storage capacity of 21,400 acre feet, with a total cost of $440,000.00, or at the rate of $20.50 per acre foot of storage capacity. The water supply is estimated by Professor Marx to be ample to fill the reservoir.

### *THE POOLS RESERVOIR SITE—*

The reservoir site known as The Pools, situated in Section 35, Township 19 South, Range 4 east, M. D. M., on the Arroyo Seco, was

surveyed in June, 1900. The title to the reservoir site vests in the Government. There are 74 square miles of tributary drainage basin. The reservoir site is of no value as the storage capacity is but 660 acre feet. A 100 foot dam would cost $115,800.00, or at the rate of $175,00 per acre foot of storage capacity.

*THE PETIT RESERVOIR SITE—*

The Petit reservoir site is situated in Section 20, Township 19 South, Range 6 East, M. D. M., on the Vaqueros Creek, and was surveyed in July, 1900. Title to this site is held by C. T. Romie. There is but 28 square miles tributary to this site. The drainage basin ranges in elevation from 350 to 5000 feet. A concrete dam, 115 feet high, would only store 1650 acre feet of water, at a cost of $139,000.00, or at the rate of $84.00 per acre foot of storage capacity.

*THE LEIGH RESERVOIR SITE—*

The Leigh reservoir site, situated in Section 16, Township 20 South, Range 16 East, M. D. M., on Vaqueros Creek, was surveyed in July, 1900. This reservoir site is naturally one of the best that was visited during the season, but the drainage basin tributary thereto is but 16 square miles, and is entirely inadequate to supply the reservoir site, which has a capacity of 14,800 acre feet, with a dam which is 150 feet high, costing $194,000.00.

*THE PINKERTON RESERVOIR SITE—*

The Pinkerton reservoir site is situated in Township 24 South, Range 10 East, M. D. M., on the San Antonio Creek. This site was surveyed in July, 1900. The property is owned by W. Pinkerton. The area of the watershed is 320 square miles, ranging from 900 to 6000 feet in elevation. The material for dam would be sandstone. A dam 50 feet in elevation, and with a maximum length of 900 feet would furnish a storage capacity of 8,200 acre feet, and cost $210,-500.00, or at the rate of $26.00 per acre foot of storage capacity.

*THE MATTHEWS RESERVOIR SITE—*

The Matthews reservoir site was surveyed in August, 1900. It is situated on San Lorenzo Creek, which stream enters the Salinas Valley from the East. The title to the site vests in private parties. It has

an area of watershed of 187 square miles, ranging from 400 to 2000 feet above sea level. A dam 100 feet high would contain 13,200 acre feet of water, and would cost $202,500.00, or at the rate of $15.50 per acre foot of storage capacity. The water supply is considered insufficient to fill a reservoir site of this magnitude.

Monterey County has contributed $1000.00 for the continuation of the investigations for a water supply for the Salinas Valley, and the Geological Survey has agreed to furnish an equal amount for this purpose, therefore, investigations will be made in the upper portion of the drainage basin for other reservoir sites. The principal work which will be conducted will be to determine the feasibility of obtaining water supply for irrigation purposes by means of pumps, the problem in this connection being largely that of motive power. From examinations made to date it is believed that the underground water supply is extensive.

Estimates will be made of the cost of bringing electric power from the Sierras for pumping purposes in this valley, and geological studies will be made to determine the feasibility of obtaining oil for fuel in the neighboring sandstone and shale hills. These investigations in this drainage basin are therefore at present incomplete. They will be pushed with vigor, and it is to be hoped that a solution will be found of the irrigation problems in this valley, which, otherwise, offers natural opportunities of a high order.

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## YUBA RIVER.

The California Water and Forest Association appropriated $450.00 and the Geological Survey allotted a similar amount for the measurement of the midsummer low water flow of the Yuba River and its various tributaries during the season of 1900. This work was placed in charge of Mr. Marsden Manson, who deputized Mr. H. D. H. Connick to take charge of this work. Mr. Connick has performed faithful service in this connection, and has prepared tables giving the daily discharge of the various tributaries of this stream. This work has been done principally at the request of the Agricultural Department, which is studying the water rights of this important river, and Mr. Marsden Manson has made an extended report on this subject to that department.

## KERN RIVER.

Mr. F. H. Olmstead, City Engineer of Los Angeles, who has been connected with the survey of several power plants on Kern River, and investigations of the possibilities of storing water in the upper reaches of that basin, has, during the past summer, extended his studies of this subject for the Geological Survey, and has assembled all available data bearing thereon, into a report to this bureau. His report is of marked interest, and will be published with the results of this season's work.

Mr. Olmstead shows a reservoir site to exist on Salmon Creek, one of the tributaries of the Kern, with a capacity of 47,000 acre feet. This water it is proposed to use to supplement the low water stages of the North Fork of Kern River, and hold the same, if possible, at a minimum flow of 400 second feet at the proposed diversion point. This volume of water used through the conduits would permit of the generation, and delivery at Los Angeles, 108 miles away, of 7825 electric horse-power. The estimated cost of accomplishing this work is $1,333,000.

It is also shown that a 65-foot dam at Menache Meadows, on the South Fork of Kern River, would provide a storage capacity of 63,700 acre feet, which, on ordinary years, would be filled from its tributary drainage basin of 165 square miles. This reservoir would be used to regulate the flow of the South Fork for the generation of power, which would be conveyed to the City of Los Angeles, 120 miles distant. The dam estimated upon would be of a combined rock fill, with an earthen upper face, and would cost $130,000.00.

The regulation of Kern River flood waters, by means of these storage reservoirs, located at high elevations in the mountains, would manifestly be to the advantage of lower irrigators.

## STONY CREEK INVESTIGATION—BY BURT COLE.

Stony Creek, the last creek to enter the Sacramento River from the West side of the Sacramento Valley, has a drainage area, as determined from the best maps available, of about 700 square miles.

*FORESTS—*

A large portion of this basin near the heads of the streams is heavily covered with commercial timber, 90 per cent of which is still on public domain, and several saw mills are located in the heart of the best forest.

Sheep and cattle are permitted to graze over the entire area unmolested, and numerous forest fires were seen during the late summer and fall, presumably of incendiary origin. These conditions are rapidly destroying the forest, which is the greatest conserver of the water supply. If this forest destruction continues it will seriously increase the amount of silt in the floods, and lead to the destruction of any reservoirs that may be built. It is urged that a reserve be created so as to avoid all private holdings possible, and to include public timbered lands.

In this connection the Sacramento Valley Development Association, on November 17th, 1900, passed the following resolutions:

*Whereas,* The waters of Stony Creek are now used for irrigation, and by their conservation and proper regulation a vast area may be brought to a much higher state of cultivation, and

*Whereas,* The experts of the United States Geological Survey, now conducting investigations along said creek, report the existence of many excellent Storage Reservoir Sites thereon, and

*Whereas,* The preservation of the forests along the headwaters of said creek is necessary to ensure a permanent water supply, and also to moderate the flow of flood waters, thereby preventing the rapid filling with silt and detritus of any reservoirs that may hereafter be constructed along said Stony Creek, or any of its tributaries.

*Therefore Be It Resolved,* That we, the Sacramento Valley Development Association, earnestly petition William McKinley, President of the United States, to set aside as a Forest Reserve such of the public lands about the head of said Stony Creek and its tributaries, as the

experts of the Geological Survey shall recommend as necessary for the protection of the water supply of said creek.

Adopted at a meeting of the Sacramento Valley Development Association, held at Oroville, California, Nov. 17, 1900.

A similar resolution was also adopted at the annual meeting of the California Water and Forest Association held in San Francisco, Cal., Dec. 13 and 14, 1900.

For the investigation of the storage possibilities in this basin, the main stream, as well as all tributaries, were visited.

Stony Creek, flowing North over the sedimentary rocks, and against the natural fall of the country, has an exceedingly low grade for a California mountain stream. It averages, for forty miles from Stony Ford, near its upper end, to the Stony Creek Buttes, less than 20 feet per mile.

At various points in this basin a fairly hard conglomerate is upturned, which has resisted erosion. Wherever this ridge has been cut by the various streams, dam sites of more or less merit are found.

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## GRINDSTONE CREEK TRIBUTARY.

On Grindstone Creek, about four miles above the point where it joins Stony Creek, a narrow gap is found, but as the basin above is not broad, and the canyon quite steep, no surveys were made.

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## SALT CREEK TRIBUTARY.

On Salt Creek, at the Devil's Gate, a similar condition exists.

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## NORTH FORK.

On the North Fork of Stony Creek, at the town of Newville, a reservoir site was found and surveyed to the 60 foot contour. The contents were found to be 25,400 acre feet, distributed over an area of 1350 acres. The reservoir would include the town of Newville and some of the most valuable lands in Glenn and Tehama Counties. The foundation for the dam is not good, and the drainage area is not such as would fill this reservoir in anything but extraordinary years of rainfall.

## BRISCOE TRIBUTARY.

At a point on Briscoe Creek, in Section 30, Township 20 North, Range 6 West, M. D. M., this tributary breaks through the conglomerate bed in a gorge which in some places is only 3 feet wide. This material is very compact, and a sample taken, weighed 143 lbs per cubic foot. Bed rock is upon the surface, and the walls of the canyon are good. It is proposed to erect at this point an overflow dam of Cyclopean Rubble, 120 feet high. Such a dam, built upon a very conservative section, it is estimated, would cost, with all its accessories, $122,000.00.

With a dam of this height there would be impounded 14,650 acre feet of water, at a cost of $8.33 per acre foot stored.

The drainage basin of Briscoe Creek, it is believed, would produce this amount of water in years of ordinary rainfall.

Below this point, in the Stony Creek Valley, is a large amount of agricultural land, at present being used almost exclusively for grain farming, which would, by irrigation, produce fruit and alfalfa successfully, at much greater profit.

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## EAST PARK RESERVOIR SITE.

At a point on Little Stony Creek, about 2 miles Southeast of the town of Stony Ford, in Colusa County, a reservoir site was found and surveyed where an 80-foot dam would impound 33,350 acre feet of water.

The conditions at this point favor a rock fill dam with side slopes 1½ to 1 on each side, to be faced with lumber 6 inches to 2 inches thick, with a concrete backing of one foot. Such a dam, with its accessories, and rights of way, would cost $165,400.00, or at the rate of $4.95 per acre foot of storage capacity. The drainage area justifies a mean draft of 25,000 acre feet therefrom.

The water from this reservoir, owing to its great distance from the plains, would have to be used largely in the Stony Creek Valley for the production of alfalfa and deciduous fruits.

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## MILL SITE RESERVOIR SITE.

At a point locally known as the "Mill Site," in Section 1, Township 21, North, Range 6 West, M. D. M., the main stream intersects the conglomerate dyke.

Owing to its proximity to the Sacramento Valley foothill lands, and the large available water supply from over 600 square miles, this site is relatively important.

A dam at this point 90 feet above the stream bed, would impound 45,750 acre feet of water. The drainage basin above should furnish this amount of water even in dry years. The dam figured upon is a loose rock fill, with side slopes of 1 to 1, and 1½ to 1, on water and down stream faces respectively, and 20 feet wide on top. The length would be 1560 feet. It is proposed to face this dam with a 3 foot wall of concrete. A spillway of 20,000 sec. ft. capacity will be provided. Such a dam, with all its accessories, would cost $698,000.00, or at the rate of $15.26 per acre foot stored.

The water from this reservoir would be available for the rich foothill land on the West side of the Sacramento Valley, near Orland and Corning, where it is possible to produce citrus fruits and olives. These lands would probably justify the construction of this dam, as with a secure water right they are estimated as worth $100.00 per acre, and without water they cannot earn interest on any value.

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## CENTRAL IRRIGATION DISTRICT.

The constructed portion of the Central Irrigation District system was visited during the past season. The water supply for this district would be derived from the Sacramento River, which at this point is a navigable stream, discharging many thousand second feet of water. The system is planned so as to command 156,550 acres of rich alluvial lands in the Sacramento Valley, between Willows and Williams. The land is well suited for irrigation, and the water supply is ample and unfailing without any regulation by reservoirs.

There has already been expended on this district approximately $500,000.00. The completion of the system was prevented by litigation which was started about 1891. It is believed that this system is the true solution of the irrigation problem for these valley lands of the Sacramento. The figures given above are based on estimates made in various engineering reports through the district. The people of this locality, who have been interviewed, apparently favor irrigation, but dread the effects of the "Wright Act." As conditions now stand they have a debt hanging over their heads, and no water for the improvement of the lands. The interest on the bonds is in default, and the situation

is unjust both to the land owners, and to the investors in these securities. It is believed that if some adjustment could be made by means of which the holders of these securities could have delivered to them the works so far constructed, with the understanding that they were to complete the works, and that the district, on its part, would be relieved of its bonded indebtedness, that a solution could be found for this most unsatisfactory problem which would be beneficial both to the bondholder and to the irrigator. If such a contract could be entered into, with the proviso that at the end of twenty or thirty years of operation the plant could be purchased by the consumers after its success had been established, and experience had been obtained in its operation, that public ownership of these works would be the ultimate result. The situation, as it stands, with half a million dollars expended on works which have great intrinsic merit and 156,550 acres of exceedingly fertile land lying in a state of semi-development, is both distressing and unbusiness-like. At present there is an inhabitant in this district to approximately every 130 acres, who is becoming bankrupt over dry wheat raising, on land where a score of scattered house gardens *demonstrate* the possibility of producing citrus fruits. Glenn County, having wonderful natural opportunities, has a school child to every 1000 acres. With a development such as has been shown to be possible in the irrigated districts of Southern California, such as Riverside, which starting with a sheep pasture, assessed under protest at 75 cents per acre in 1870, now supports about 10,000 inhabitants, or a citizen to every 1 1-3 acres irrigated, and shipped over 4000 car loads of citrus fruits during the past season, this population might be increased from 50 to 100 fold. Under the existing law it is impossible for an organized irrigation district to alienate any of its property, and it will be necessary to obtain such legislation, which will provide for the transfer suggested above.

It is therefore urged that some provision should be made for conditions such as exist in the Central Irrigation District, and other like organizations that are confronted with similar conditions at the next session of the legislature.

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## CONCLUSION.

In conclusion it might be stated that Glenn and Colusa Counties are exceedingly favored in their natural resources. Reservoir sites have been found and surveyed, which demonstrate the possibility of irri-

gating the mountain valleys of Glenn County on an exceedingly conservative commercial basis, and it is confidently believed, that it is possible to build up a great irrigation community in the Sacramento Valley by the perfection of the works of the Central Irrigation District and the construction of the Mill Site reservoir. This County is particularly blessed with an abundant water supply; with arable lands of the finest quality, and with climatic conditions which justify all varieties of horticulture and agriculture known in the State of California. Instead of being a sparsely settled district, with undeveloped resources, it is believed, from the investigations made, that this locality should support a population, when these natural opportunities are utilized, of over 100,000 people. This, of course, will require education and agitation. The only element lacking in this situation is human energy.

## SUMMARY OF CACHE CREEK INVESTIGATION.—BY A. E. CHANDLER.

The Geological Survey has been particularly fortunate in obtaining the assistance of Mr. A. E. Chandler, Instructor of Engineering, at the University of California, to conduct the investigations for the storage of water on Cache Creek.

A reconnaissance was made of this drainage basin during the past season by Mr. Chandler, and examinations made of possible reservoir sites. Those which proved, on inspection, to be satisfactory were surveyed. The examinations included the inspection of the Clear Lake Reservoir site, and the assemblage of much data which was the result of previous surveys by the Geological Survey and by the Southern Pacific Railroad, as well as by certain power companies.

Clear Lake is situated approximately 75 miles North from San Francisco.

The Geological Survey was assisted by the California Water and Forest Association, and by the Woodland Chamber of Commerce, each of these three institutions contributing $250.00 to the work. In addition to this the Geological Survey has rendered such assistance as lay within its power in furnishing consulting engineers and instruments, and general direction of the work, at its own expense. Four reservoir sites were examined, two of which were found to be meritorious. The problem of the water rights on this stream have been studied by Mr. J. M. Wilson, of the Department of Agriculture. The investigations of Mr. Chandler were restricted to include simply the engineering features of the work. However, in making estimates along these lines, suitable allowance has been made for possible damages that might occur to private parties.

It is believed that there is a large area of land upon which water could be used to commercial advantage, for the production of high grade fruits, particularly in Capay Valley and underlying the reservoir sites which have been surveyed. A series of water measurements were made on many streams, and a permanent gauging station will be established. A preliminary examination was made of the underground water near Woodland, but most of the time and effort was put on the examination of reservoir sites.

The Twin Valley reservoir site was inspected, but it was not considered of value, as there is but 5 square miles of tributary drainage basin. There is, however, a fair reservoir and damsite at this point.

Long Valley, on Long Creek, was visited. This site is about 6 miles long, with an average width of approximately 1000 feet. The drainage basin, however, is insufficient, containing only about 30 square miles, and the dam site is poor, and was consequently rejected.

Little Indian Valley, on the North Fork of Cache Creek, was surveyed. This site is about 5 miles long, and from one-half to three-quarters of a mile wide. The land in the reservoir site is poor and about one-half of it is cultivated. The capacity of this reservoir site, at the 100 foot level, is 37,625 acre feet. At the 125 foot level, it is 69,000 acre feet. There is back of this site approximately 100 square miles of drainage. It is probable that this reservoir could not be completely filled during the years of minimum rainfall to the 125 foot level, or 69,000 acre feet in volume. By holding over 29,000 acre feet of water from average and years of excessive precipitation, it is believed that a supply of 40,000 acre feet would be available. Judging from rainfall records in this drainage basin during the last 14 years, there would have been 12 years of full supply; one year with a deficit of 6,000 acre feet, and during the year 1898, which was a dry year following a dry year, there would have been a deficit of 23,000 acre feet. This deficit, of course, is serious, but it has been found during the past five years in Southern California, that it is entirely possible to preserve orchards and crops during one or two seasons of deficit supply without serious injury, and it is believed to be a truer economy to accept this situation rather than to design works which are practically prohibitive, and which will not be called upon to perform their full service oftener than once in every twenty or thirty years. 40,000 acre feet are therefore considered as the available supply from this site.

Quarries suitable for the construction of the dam are situated near by, and above it in elevation. The rock consists of hard slates. It is estimated that a concrete dam to a maximum height of 130 feet to impound water to the 125-foot level, could be built for $453,000.00, or at a cost of $6.56 per acre foot of storage capacity obtained. If the available supply is considered 40,000 acre feet the cost would be at the rate of $11.33 per acre foot of water available. It is, therefore, a good reservoir site, and it will undoubtedly be utilized at some time in the future for irrigation purposes. For the raising of deciduous fruits and cereals, probably 1½ acre feet of water would be a sufficient annual supply. If one-third of this amount could be obtained during

the spring months of March, April and May, from the natural flow of the unregulated portions of the creek, and one acre foot would be available from the reservoir for use during June, July and August, it is believed that this amount would be sufficient; in other words, 40,000 acre feet should be sufficient to maintain a satisfactory water supply for 40,000 acres in this locality.

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## CLEAR LAKE.

In considering the problem of using Clear Lake for a reservoir site the effort was made in the plans to so regulate this site as to avoid large damage to property. Records of the Lake's levels, from 1874 to 1888, have been kept by Captain Floyd, of Kono Tayee, and have been very kindly furnished to the Geological Survey. Records by Mr. F. H. Porter, of Kono Tayee, and by Captains Rumsey and Atherton, of Lakeport, have been furnished for the period from 1888 to date. These records are of very great value, and are used as the basis of the computation of the available supply from this lake, checked by computations of run-off and other data.

To allow for 80,000 acre feet for each and every irrigation season during the past 26 years, the outlet would have to be fixed so as to control a minimum elevation of 90 feet, and a maximum elevation of the lake of 106 feet above an assumed datum which has been used in this and other reports. In 1898 the lake fell to an elevation of 97.75 above this datum, and in March, 1876, it rose to an elevation of 108.39 feet, so that very little disturbances of the lake within these natural limits, is contemplated. Two feet of storage capacity in this lake would be sufficient, under all ordinary conditions, to furnish the supply estimated upon therefrom.

The lake is twenty miles long and seven miles in maximum width, and contains 65 square miles in total area, ranging from 35 to 50 feet in depth. There are 417 square miles of drainage area tributary thereto . The water is sufficiently pure for irrigation purposes. The storage capacity, from the 106 to the 110-foot levels, is 180,671 acre feet, which is equivalent to 499 cubic feet per second for an irrigation season of 182½ days. The evaporation, which from a body of water of such extensive area is an exceedingly important factor, has been considered as 53½ inches.

Further observations are needed to more carefully determine this important fact, and an effort will be made to start these records.

By the methods cited above, and as a result of the careful study of the situation, it is believed that 80,000 acre feet could be confidently relied upon from this source, and it is possible that the amount will be as great as 100,000 acre feet available during the irrigation season.

Surveys made by Mr. William Ham Hall, for the U. S. Geological Survey, in 1889, of the outlet of this lake, have been used as a basis for the computation of cost of constructing works thereon. It is estimated that this work can be accomplished for $452,484.00. Consider 80,000 acre feet as the available supply, and the cost will be at the rate of $5.66 per acre foot of storage capacity, and if 100,000 acre feet is obtained this unit rate will fall to $4.52.

These figures show that Clear Lake reservoir site, economically considered, is one of the very best storage sites that has yet been found in California.

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## SUMMARY.

It is therefore shown by Mr. Chandler's report that there is a possibility of economically irrigating by proper storage regulation from Cache Creek, as follows: Little Indian Valley site, 40,000 acre feet at $453,000.00. Clear Lake, 80,000 acre feet for $452,484.00, making a total available supply, annually, of 120,000 acre feet, for $905,484.00, or at the average rate of $7.55 per acre foot of available supply. If dry lands in this neighborhood are considered to be worth about $30.00 an acre, and irrigated lands from $60.00 to $100.00 an acre, the economy on the basis of land values alone is thus shown to be very great. On the basis of population, in Southern California it would not be an extreme statement to say that this would justify the continued support of a population of 60,000 souls. Mr. Chandler has been assisted in his report by Mr. J. H. Quinton, Consulting Engineer, of Los Angeles.

## MIDSUMMER GAGING OF STREAMS.

By S. G. Bennett, Assistant Hydrographer.

In pursuance to instructions the San Joaquin, Kings, Stanislaus, and Tuolumne rivers were visited and the flow of each measured Aug. 9 to 11th, and judged not to have reached their lowest stages.

The work was discontinued until Sept. 1st, the time at which the low water measurements of 1899 were commenced.

The work was again taken up on Sept. 1st, the San Joaquin river being gauged on that date. The Tule river was gauged at the head works of the Pioneer Canal at the beginning of a local rainstorm on Sept. 2nd, and represents the lowest stage of water for the year. The rain continued on the night of the 2nd of September, and in the mountains on Sept. 3rd.

The Kawea river was visited and gauged on Sept. 3, 1900. The river was rising slowly at the time, so this measurement does not represent the lowest stage of the river.

From a study of the rain fall reports of the weather bureau, it is evident that the discharge as given in the table which will be published in a detailed report by the Geological Survey fairly represents the low water stages for the year 1900 of the streams flowing into the San Joaquin and Sacramento Valleys, with the exception of the Kawea river. A copy of this data can be obtained, if desired, upon application to J. B. Lippincott.

The work was done with the utmost dispatch possible and with the least expenditure, the total cost, not including office calculations, being $335.90. Of this amount $167.55 was paid by the California Water and Forest Association and $168.35 by the United States Geological Survey.

## CONCLUSION.

In conclusion it may be stated that as a result of the expenditure of approximately $10,000.00 it has been shown that the following amounts of water can be obtained and made available for irrigation at an average expense of $8.03 per acre foot on the following streams in the manner given:

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## SUMMARY OF RESULTS EXCLUSIVE OF THE SALINAS (INCOMPLETE) AND KERN RIVER INVESTIGATIONS.

| *Stream. Locality*— | Capacity available acre-feet. | Total cost. | Cost per acre-foot. |
|---|---|---|---|
| Kings River— | | | |
| Clark Valley | 223,224 | $2,013,949 | $ 9.02 |
| Electric Pumping Plant (eight months' operation) for installation | 216,000 | 1,277,500 | 5.91 |
| Stony Creek— | | | |
| Briscoe | 14,650 | 122,000 | 8.33 |
| East Park | 25,000 | 165,400 | 6.62 |
| Mill Site | 45,750 | 698,000 | 15.26 |
| Cache Creek— | | | |
| Little Indian Valley | 40,000 | 453,000 | 11.33 |
| Clear Lake | 80,000 | 452,484 | 5.66 |
| Total | 644,624 | $5,182,333 | $ 8.03 |

The addition of this amount of water for irrigation purposes to the resources of the interior valleys of California is believed to be sufficient to justify an increased population in those districts of from 100,000 to 200,000 souls. Deducting for the cost of construction it is believed that this would result in a direct increase in land values of irrigated areas, of fully twenty million dollars, irrespective of increase in town and city property, which would be a necessary sequence.